

**INNOVATIVE
TECHNOLOGY**

SUMMARY REPORT

for the

Large Scale Demonstration and Deployment Project of Hot Cells

**DEMONSTRATION OF THE RADPRO®
DECONTAMINATION PROCESS**

AUGUST 2003

Demonstrated at:

West Valley Demonstration Project

West Valley, New York

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TECHNOLOGY
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for the
Large Scale Demonstration and Deployment Project of Hot Cells*

Purpose of this Document

Innovative Technology Summary Reports (ITSRs) are designed to provide potential users with the information needed to quickly determine whether a technology would apply to a particular environmental management problem. These reports are also designed for readers who may recommend that prospective users consider a technology.

Each ITSR describes a technology, system, or process that has been developed and tested with the funding from the Department of Energy (DOE) Office of Science and Technology (OST). The report presents the full range of problems that a technology, system or process will address and its advantages to DOE in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. ITSRs are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

TABLE OF CONTENTS

SUMMARY	1
TECHNOLOGY DESCRIPTION	5
PERFORMANCE	8
TECHNOLOGY APPLICABILITY AND ALTERNATIVES	16
COST	21
OCCUPATIONAL SAFETY AND HEALTH	24
REGULATORY AND POLICY ISSUES	26
LESSONS LEARNED	27
REFERENCES	28
ACRONYMS AND ABBREVIATIONS	29

SECTION 1 SUMMARY

Technology Summary

Accomplishing the decontamination of radioactive hot cells, like those currently undergoing cleanup at the West Valley Demonstration Project (WVDP) and other sites within the DOE complex, requires the removal and packaging of contaminated equipment as well as the removal of contamination from walls, ceilings and equipment surfaces inside the cells. Standard methods for removing surface contamination, such as vacuuming or using strippable coatings, are effective for removing particulate matter, but cannot remove contamination that is chemically bonded (or fixed) to a surface. More aggressive methods for removing surface contamination, such as Ultra High Pressure (UHP) water jetting, vacuum steam cleaning or using a chemical decontamination agent, can result in the production of large volumes of liquid waste and/or mixed waste, which places limitations on how the waste can be treated and disposed.

Environmental Alternatives Inc. (EAI) RADPRO® technology is a decontamination process that employs chemical reagents to sequentially solubilize, complex with and remove radionuclides from surfaces and, to some degree, remove contaminants from within porous media. The process can remove fixed and smearable contaminants from metals and has been demonstrated previously to remove (extract) embedded contaminants from concrete without degrading the concrete. The benefits of the process lies in the use of non-hazardous formulations to effect decontamination and the production of a minimal volume of secondary waste. Additionally, this secondary waste is compatible with existing commercial and federal waste disposal site waste acceptance criteria (WAC).

The EAI RADPRO® process has been successfully demonstrated at the West Valley Demonstration Project (WVDP) for decontamination of stainless steel components used in the handling and storage of spent nuclear fuel. The radionuclide contamination removed was predominantly Co⁶⁰ and Cs¹³⁷ that had become chemically bonded with the steel substrate metal oxide film and was therefore considered to be fixed contamination. Considerable loose contamination was also present as a result of radioactively contaminated water from the spent fuel pool being adsorbed onto the surface of the stainless steel oxide film. The objective of the decontamination demonstration was to determine the effectiveness of the EAI RADPRO® process to achieve a reduction in radiation dose such that it may be correlated to the reduction of dose rates in hot cells to allow manned access following decontamination. The active deployment of the EAI RADPRO® process in a hot cell to achieve such dose reduction was not a component of the demonstration. Such use was considered for a follow-on deployment once the application, removal, and waste handling issues had been proven during the demonstration on spent fuel handling and storage equipment.

The process was demonstrated using a hands-on methods which would be readily transferable to remote deployment using PaR manipulators and other manipulators typically in use in hot cells. Support for the EAI RADPRO® process in terms of development of chemical formulations and sequencing of applications, tailored to specific substrates, geometry and contaminants, is performed from a mobile laboratory housed entirely within in a portable trailer. No hazardous constituents are in the solutions, except for any hazardous constituents that were associated with the extracted contaminants. The improved technology, mobilized from New Hampshire to New York State and utilized over a three week period resulted in a cost of \$ 78,000. Stripping out demonstration specific costs, the unit cost for utilization of the EAI RADPRO® technology was \$15.50/ft².

Demonstration Summary

The two phase demonstration of the EAI RADPRO® process discussed in this report was conducted at the WVDP site. The first phase was performed in the Fuel Receiving and Storage (FRS) building, where it was applied on a surface inside of a trench next to a decontamination stall where casks holding spent fuel assemblies were once washed down. Consequently, contamination was predominantly water soluble radionuclides with an affinity for deposition on and within metal oxide films. The second phase was performed in the Analytical and Process Chemistry laboratory (A&PC lab) on two sections of pipe from a spent fuel rack. They had been in the pool for approximately 30 years and therefore the conditions for migration and or inclusion of cationic radionuclide species onto or into the metal oxide film of the fuel racks were well established.

The demonstrations that were conducted using EAI's RADPRO® process involved the sequential application of three chemical formulations to lightly wet the surface with an atomized spray of the process chemicals. This was followed by light surface scrubbing using a Scotchbrite® pad to work the chemical formulations into the surface, followed by a 30-minute period of residence on the surface to allow the chemicals to react with the substrate. After this 30-minute period, the thin films were rinsed again with a light atomized spray and the surface wiped with a cloth to remove the reaction products and rinse solution. The purpose of the sequential application is to take advantage of three chemical reactions:

- 1) Degreasing and removal of deposits that may be preventing access to the pathway that the radionuclide contaminant took when it became adsorbed or incorporated onto/into the substrate surface,
- 2) Reacting with the radionuclide contaminant to break the electrostatic or chemical bond associating it with the substrate, and

- 3) Complexation with organic molecules to sequester and finally remove by rinsing and swabbing complexed radionuclide contaminants off the surface.

Decontamination performance was tested using a method of comparison of the EAI RADPRO® process with established WVDP hands-on decontamination processes. This was done to determine the efficacy of decontamination and the cost of deployment. The first method involved decontaminating one half of the Decontamination Stall trench using TLC Stripcoat®. The other half of the trench was decontaminated using the EAI RADPRO® process. The TLC Stripcoat® was applied in the same manner as the EAI RADPRO® process, including light scrubbing with Scotchbrite® pads. The second decontamination performance test, conducted in the A&PC lab, used another proprietary decontamination agent, Contrad 70® to compare relative cost and performance. The two processes (EAI RADPRO® and Contrad 70®) were applied in an identical manner to two sections of the spent fuel rack pieces of pipe. This second test involved multiple applications, scrubbing, dwell times and rinsing before final removal with a cloth.

In all the demonstrations the EAI RADPRO® process achieved higher decontamination factors than the baseline technologies; removing all loose contamination to the limits of detection and the fixed contamination to area background levels. Since background radiation levels in the Decontamination Stall trench area were high, this prevented obtaining a true reading of the efficacy of removal of fixed contamination, though superior performance over the TLC Stripcoat® was confirmed by the contamination found in the final waste form. It was an order of magnitude higher for the EAI RADPRO® waste. Other performance areas evaluated during demonstration testing included ease of use; expected worker involvement; volume and type of secondary waste generated; rate of application and removal; projected operating costs; and estimated deployment time, including equipment set-up and disassembly.

Overall test results showed that the EAI RADPRO® process is a functional decontamination method suitable for decontamination to achieve dose reduction in hot cells (and many other applications). Although the process was not deployed in a hot cell, the evaluation performed during the demonstration concluded that such use is practicable with minimal modification to the process. The process is a viable method for decontamination of surfaces, that is simple to configure, easy to use, and capable of generating low volumes of solid (dry) waste that are easy to manage.

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Licensing

No licensing involved

Permitting

No permits involved.

SECTION 2 TECHNOLOGY DESCRIPTION

Overall Process Definition

Standard processes used to accomplish surface decontamination are effective in the removal of loose contamination, but are far less effective in removing contamination that is chemically bonded (or fixed) to metal surfaces. Aggressive techniques can be used to remove fixed contamination from metal surfaces. However, they are also expensive to install, labor intensive, and produce large volumes of liquid (and frequently mixed) waste that requires further treatment and disposal. For example, various kinds of electrochemical/wet decontamination methods produce aqueous wastes that require treatment for RCRA metals.

The EAI RADPRO® decontamination process has been identified as a process capable of achieving re-categorization of Contact Handled Transuranic Waste (CH-TRU) to Surface Contaminated Objects (SCOs)/Low Level Waste (LLW). This is achieved through sequential application of proprietary decontamination formulations to achieve removal of deposited, chemi-sorbed and chemi-bonded radionuclide contamination from substrate surfaces. Secondary waste produced is a low volume of solid waste that conforms with existing waste disposal site WACs.

The process employs a sequence for applying and removing each of the chemicals. In most projects, three chemical formulations are used. Chemicals are applied in low volumes as a light atomized spray to minimize the amount used and the volume of waste produced. The chemicals are lightly scrubbed into the contaminated surfaces with abrasive pads for a predetermined period of time (typically 30 minutes), and then rinsed and removed by wiping with a cloth (vacuuming is also possible for large scale applications). The application and removal of all three solutions is one cycle of the process. Sampling and/or radiation surveys can be performed at the end of any step in the cycle and they will often show reductions in levels of radionuclide contamination of 90% or more per step.

The EAI process has been previously deployed at the Rocky Flats Facility in Golden Colorado. To help expedite closure activities at Rocky Flats, an effective decontamination method was needed to reduce items such as glove boxes from CH-TRU waste levels (>100nCi/g) to LLW. In the last quarter of FY2000, EAI was selected to demonstrate the RADPRO® process to prove its effectiveness in meeting the SCOs criteria for decontaminating large items like glove boxes. By the end of FY2001, the project decommissioned five major glove box systems. Expected TRU waste volumes had been reduced by approximately 457 cubic meters or 31% from the predicted volumes for the glove box systems disposed as SCO. This success prompted the LSDDP to investigate the opportunity to evaluate the EAI RADPRO® process for deployment at the WVDP for the decontamination of hot cells.

System Operation

The chemical extraction process employs as many as 25 different components, typically in three separate chemical formulations, which are used in sequence to accomplish the extraction of contaminants from substrates. The first two chemicals are surface preparation formulas (0300 and 0200) which contain complex blends of acids and other chemical agents to clean dirt, oil, grease and other interferences from the surface. These blends solubilize inorganic and organic material and prepare the substrate by establishing required conditions for the extraction step. More importantly, the sequencing and timing for application of these chemicals allows for a synergistic chemical combination. Each formula has an important role on its own, but when 0200 is overlaid on 0300, the resulting, complex compounds have a powerful ability to put even the most insoluble, inorganic oxides into solution.

The extraction blend (0100) penetrates below the surface and binds itself to the contaminants, then pulls horizontally and vertically through the microscopic pores to the surface. Additional components of the formula encapsulate the contaminants to prevent them from re-contacting and thereby recontaminating the surface, keeping them in suspension until they can be removed during the rinse step.

The chemical formulations used in the technology satisfy OSHA Section XVIII, 29 CFR 1910.120, containing no hazardous components regarding flammability or reactivity (as per 40 CFR 261). They are carefully designed to prevent the release of any harmful fumes. Even though low and high pH blends are used in the process, the pH at disposal is close to 7, and the liquids are non-corrosive. Additionally, these products do not contain components which would classify them as hazardous for disposal under Toxic Characteristic Leaching Procedure (TCLP) testing. As a result, the waste stream from a project can be characterized based on the contaminants which were extracted.

The chemistry is based on several hypotheses relating to contaminant migration and removal. One hypothesis is that contaminants migrate along the grain boundaries and into pores and microscopic voids of a material, even for seemingly non-porous media. Mobility of the contaminants, time, and secondary forces often drive these contaminants to deeper levels in the substrate. Another hypothesis is that contaminants tend to become chemically or electrostatically bonded to the substrate. In many cases, the time between the contamination event and decontamination efforts will allow the contaminant migration pathways to become partially closed.

The EAI RADPRO® process works by:

- Reopening the pores and capillary pathways to the maximum extent possible,
- Penetrating into the pores as deeply as possible,

- Breaking the electrostatic and chemical bonds which hold the contaminants in place,
- Complexing or sequestering the contaminants to prevent re-contamination, and
- Allowing complexed contaminants to be removed from the surface by rinsing and wiping.

The technology is a tailored process for applying and removing each of the chemicals in the right sequence and combinations to achieve optimal results. In most projects, three different chemical formulas are used. Chemicals are applied in low volumes as an atomized spray to minimize generation of secondary waste and subsequent treatment of wastes. After being applied, the chemicals are scrubbed into the contaminated surfaces, left to react with the surface for a defined time, and rinsed and removed. The application and removal of all three formulas constitutes one cycle of the process. Sampling and/or surveys can be performed at the end of any cycle and often shows a reduction in contamination of 90% or more per cycle.

Chemicals are normally atomized and applied as a fine spray to minimize the volume of chemicals used and the resultant waste. Large volumes are not necessary for the extraction process to be successful. In fact, typical liquid waste volumes are only 0.04 to 0.10 gallons per square foot for an entire project. The extraction process does require that the chemicals make good contact with all surfaces. To do this, the chemicals are rubbed onto the surface manually or with automated machinery. Crew size depends on the size of the job, time requirement, and available working space.

The EAI RADPRO® process has a certain elegance when compared to the traditional strong mineral acid decontamination processes, which achieve similar results by complete surface dissolution to the maximum depth of contaminant migration. This approach of complete surface dissolution is disadvantageous by comparison to the EAI RADPRO® process for two reasons. Unbuffered strong mineral acids exhibit corrosive properties that designate them as hazardous chemicals and the concentrations of acids needed to achieve such a degree of surface dissolution require treatment of the secondary waste produced. Such treatment is complex and results in a large amount of unreacted acid. This generates large volumes of inorganic salts that are precipitated during neutralization and treatment, to become radioactive waste. There are a number of more recent, low concentration, and higher temperature chemical decontamination processes that have removed these burdensome characteristics. However, these processes require complex and costly engineered systems in order to deploy.

SECTION 3 PERFORMANCE

The demonstration of the EAI RADPRO® decontamination process involved various tests. The tests were structured to evaluate system performance according to the Test and Evaluation Categories listed in Table 3.1 - System Testing and Evaluation Summary. The tests were divided into two phase: Phase 1 involved the decontamination of a trench, and Phase 2 required decontamination of pieces from a spent fuel rack.

Table 3.1 - System Testing and Evaluation Summary	
Test Category	Evaluation Method
Efficiency	Measurement of the efficiency of removal of radionuclide contamination using hand held dosimeters and scintillation counters.
Ease of Use	Total time needed to complete equipment set-up, gel application and removal, and equipment disassembly and level of difficulty experienced during these operations.
Worker Involvement	Number of workers needed to deploy the process.
Waste Generation	Measurement and tracking of the volume of chemicals and rinse solutions used, and the amount of secondary waste generated during system operation.(including PPE).
Application/ Removal	Time needed to apply and remove chemicals.
Deployment Estimate	Total time taken to deploy the process, including equipment set up and disassembly/cleanup operations.

Test Plan

Phase 1: Decontamination Stall Trench Test

In order to eliminate the bias that is often seen in single test applications, a baseline decontamination process was deployed along with the EAI RADPRO® process. The baseline process is the use of strippable coatings. The strippable coating chosen for use as a comparison to the EAI RADPRO® process was TLC Stripcoat®, a coating that has been evaluated and applied at numerous DOE sites and is commonly used at the WVDP.

The Decontamination Stall trench is located inside the controlled area with loose contamination present on exposed surfaces. The presence of loose contamination required the use of PPE in the form of Tyvek® coveralls, gloves, boots and chemical respirator. The latter being a precaution against the potential for the TLC Stripcoat® to evolve small quantities of gaseous ammonia during application as well as the presence of amines in the EAI RADPRO® process. (The MSDS for both processes do not require respiratory protection if used in well ventilated areas.)

A single entry was made into the area to apply the TLC Stripcoat® and carry out the EAI RADPRO® decontamination process. This involved two operators and one radiation protection technician. Previously, the area had been sectioned into a grid for a radiological survey in order to determine the efficacy of the process.

The decontamination was performed as follows:

West Valley Nuclear Services Company personnel under the technical direction of an EAI representative applied the EAI-supplied RADPRO® chemical decontamination solutions to one half of the length of the Decontamination Stall trench. TLC Stripcoat® was applied to the other half. Radiation surveys were performed before application and after removal of the EAI RADPRO® decontamination solutions and the TLC Stripcoat® to compare their relative effectiveness of decontamination.

Materials/Equipment List

Decontamination Chemicals:

- EAI stock solution RADPRO® 0100 (Provided by EAI vendor)
- EAI stock solution RADPRO® 0200 (Provided by EAI vendor)
- EAI stock solution RADPRO® 0300 (Provided by EAI vendor)
- De-ionized water (DI water)
- TLC Stripcoat®, approx. 10 liters
- Scotchbrite® pads
- Wipes (shop cloths)
- Four 500 ml (or larger) plastic spray bottles for application of EAI RADPRO® chemicals and DI water

Preparing Test Solutions in EAI Trailer Mobile Laboratory

RADPRO® chemicals were made up in the following manner; 200 ml of 0100 stock solution was added to a spray bottle labeled "Undiluted 0100 solution", 150 ml of 0200 stock solution was mixed with 50 ml of 0300 stock solution in a spray bottle labeled "0200/0300 solution mixture", and 20 ml of 0300 stock solution was mixed with 180 ml of DI water in a spray bottle labeled "10% Diluted 0300 rinsate solution".

Survey Pre-Decontamination

The trough was divided into a 100 cm² grids; radiological contamination surveys were performed and preliminary survey results for both fixed and loose contamination were recorded.

Decontamination of the Decontamination Stall Trench Using TLC Stripcoat®

TLC Stripcoat® was applied to designated areas of the Decontamination Stall trench with mechanical action using Scotchbrite® pads. Additional TLC Stripcoat® was applied normally (without scrubbing) to ensure that the coating was thick enough to permit stripping after drying. The TLC Stripcoat® was allowed to dry overnight before removal. Following the curing period, the dry TLC Stripcoat® was peeled from the surface and compressed down by hand to minimize the volume for disposal. The actual volume of TLC Stripcoat® produced from the 7 ft² treated area was approximately 11 in³ which was disposed of as LLW.

Following removal of the stripcoat, the area was surveyed for loose and fixed contamination. The results are presented in Table 3.2.

Decontamination of the Decontamination Stall Trench Using EAI RADPRO® Solutions

The "0200/0300 solution mixture" was sprayed onto the selected area using a light spray (to just wet the surface) and scrubbed lightly using a Scotchbrite® pad. A reaction time on the surface of 20 minutes was allowed for the chemicals to react with the substrate. The surface was then rinsed with "10% Diluted 0300 rinsate solution" to remove all traces of residual chemicals and extracted contaminants and wiped dry with shop cloths.

Following this step, the "Undiluted 0100 solution" was applied sufficiently to just wet the surface and the "Undiluted 0100 solution" lightly scrubbed into the surface using a Scotchbrite® pad. An additional 20 minutes was allowed for the 0100 solution to react. The surface was then rinsed with "10% Diluted 0300 rinsate solution" and wiped dry with shop cloths. Once the surface was dry, a survey for loose and fixed contamination was performed and results recorded.

The decontamination process may be repeated depending upon survey results indicating the degree of decontamination achieved and the desired decontamination target levels established at the start of a project.

All dry waste cloths, Scotchbrite® pads and secondary wastes were placed in a waste bag, with a 1/4 cup of absorbent material added to the bag as a precaution to ensure that no free liquid was present in the waste stream. A total of 196 in³ of waste were generated and the waste was disposed of under a LLW waste profile.

In addition to process waste, both the EAI RADPRO® and TLC Stripcoat® processes generated additional LLW in the form of used PPE, one set per operator and 1 set for the radiation protection technician. The PPE was comprised of overboots, Tyvek coveralls and gloves, with the respirators being laundered and re-used. A total of approximately three ft³ per person was generated. The most important factor here was that the TLC Stripcoat® required a subsequent entry to remove the dry coating, whereas the EAI RADPRO® process was completed in a single entry. As a consequence, the TLC Stripcoat® generated twice as much LLW, even though the actual amount of decontamination secondary waste was much less than EAI RADPRO® process, eleven in³ compared to 196 in³. (It should be noted that the 196 in³ could have been reduced by two thirds had the waste cloths been compressed and immobilized with tape.)

Phase 2: A&PC Lab Test

For the laboratory test, an alternative decontamination baseline technique was desired that more accurately mirrored the EAI RADPRO® process. A proprietary decontamination agent which is used in the A&PC lab was identified for comparative testing. The agent was a potassium hydroxide based solution with the trade name Contrad 70® and has proprietary additives to assist in decontamination. Typically, Contrad 70® is applied as an immersion process over 12 to 24 hours. Therefore, its application should not be considered representative of its performance as a laboratory equipment decontamination process. It was chosen because of its successful use at the WVDP as decontamination agent in the A&PC lab.

The items chosen for the lab test were sections of fuel rack that had been in the WVDP spent fuel pool for several decades, with resultant contamination being both fixed and loose with radiation dose rates being in the range of 40 - 80 mR/hr beta/gamma at 2 inches. The sections were each approximately 1 foot long, 1½ inch diameter, hollow cylinders with a wall thickness of ⅛ inch. The sections which had been cut had the ends taped because of the sharp edge left by the band saw. It was decided to leave the edges taped to minimize any potential hazard from the cut ends, even though cut proof gloves were also used. An unwanted aspect of leaving the tape in place was that the ends of each section were not decontaminated, leaving approximately ¼ inch at each end which retained some degree of contamination beneath the tape.

The decontamination effort was conducted inside the A&PC lab glove box. Each process was evaluated independently. The EAI RADPRO® process was carried out using the sequential steps as performed in the Decontamination Stall trench trial. Secondary waste consisted of the Scotchbrite® pad and cloths used in the rinsing steps. The volume of waste was again approximately 190 in³, even though the area treated was considerably smaller. The explanation for this is that both the Scotchbrite® pad and the cloths used could have continued to be used for a much larger area than that presented by the fuel rack section. It would have been possible to cut down both

the cloths and Scotchbrite® pad to suit the size of the fuel rack section but glove box operations with cut proof gloves severely hamper dexterity. The smaller pieces would have been very difficult to manipulate. The waste generated is typical of simple decontamination operations such as “wipe down” that are often performed to reduce the hazard of loose contamination, yet the decontamination effectiveness is equal to that of complex aggressive mineral acid processes (which typically generate far more waste than “wipe down” decontamination efforts).

Results of the A&PC lab decontamination test are presented in Table 3.3. These show that the EAI RADPRO® process performed extremely well, removing radionuclide contamination to yield a residual contamination level close to unrestricted release, after a single application of the process. A decontamination of factor (DF) of 200 was realized when the pre- and post-dose rates are compared. This is on a par with aggressive mineral acid decontamination processes. The process demonstrated its ability to achieve dose reduction and is an appropriate technology to deploy in the pursuance of dose reduction in hot cells to allow manned access.

Results

Review of the data presented in Tables 3.2 and 3.3 demonstrate the EAI RADPRO® process performed better than the TLC Stripcoat® and the Contrad 70®.

Quantification of relative effectiveness in terms of dose reduction for the Decontamination Stall Trench demonstration is not possible because of the high background in the general area and can only be inferred by the dose rates on the secondary waste produced. The results were:

- TLC Stripcoat® **2 mR/hr** window open on contact
0.2 mR/hr window closed on contact
- EAI RADPRO® **50 mR/hr** window open on contact
15 mR/hr window closed on contact

From these dose rates it can be observed that the EAI RADPRO® process was considerably more effective than the TLC Stripcoat® in removing fixed contamination. The higher dose rates on the EAI RADPRO® waste are attributed to fixed contamination because both processes removed loose contamination; the EAI RADPRO® completely, and the TLC Stripcoat® the bulk of it.

For the FRS fuel rack sections, the EAI process reduced virtually all of the 30 mR/hr contamination. Contrad 70[®] achieved a DF of less than 2. In order to confirm the effectiveness of the EAI RADPRO[®] process, the FRS fuel rack section treated with Contrad 70[®] and having a residual dose rate of 10mR/hr after treatment, was further treated by a single application of the EAI RADPRO[®] process. This EAI RADPRO[®] treatment reduced the dose to background levels (just above the free release limits).



Based on the decontamination performance, the low volume of secondary waste produced, ease of application and removal, and the non-hazardous constituents utilized, the tests determined that the EAI RADPRO[®] process performed better than the existing baseline technologies.





Decontamination Stall Trench Before Decontamination With EAI RADPRO[®] Process

Table 3.2 Results of the FRS Decon Stall Trench demonstration

Pre-Decontamination Survey of the FRS Decon Stall Trench

	cpm Beta 270 K	cpm Beta 270 K	cpm Beta 300 K	cpm Beta 280 K	cpm Beta 270 K	cpm Beta 300 K	cpm Beta 330 K	cpm Beta 390 K	cpm Beta 350 K	cpm Beta 300 K	
	Drain line - source of gamma radiation underneath the stainless steel trench surface										
	cpm Alpha 48	cpm Alpha 25	cpm Alpha 56	cpm Alpha 50	cpm Alpha 35	cpm Alpha 36	cpm Alpha 40	cpm Alpha 39	cpm Alpha 29	cpm Alpha 36	
Smear dpm/100cm2-Alpha (* denotes less than)	75	39	20*	20*	20*	200	20*	20*	29	20*	
Smear dpm/100cm2-Beta	4,015	3,056	11,250	9,375	7,500	15,000	7,500	6,250	7,500	21,250	

**Post EAI RADPRO Chemical Extraction Decontamination Survey
(fixed beta attributed to shine from gamma source underneath trench)**

						cpm Beta 280 K	cpm Beta 320 K	cpm Beta 360 K	cpm Beta 330 K	cpm Beta 280 K	
	Drain line - source of gamma radiation underneath the stainless steel trench surface										
	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	cpm Alpha 5*	cpm Alpha 5*	cpm Alpha 5*	cpm Alpha 5*	cpm Alpha 5*	
Smear dpm/100cm2-Alpha (* denotes less than)	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	20*	20*	20*	20*	20*	
Smear dpm/100cm2-Beta	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	Stripcoat Decon Trial	100*	100*	100*	100*	100*	

**Post TLC Strip coat Decontamination Survey
(fixed beta attributed to shine from gamma source underneath trench)**



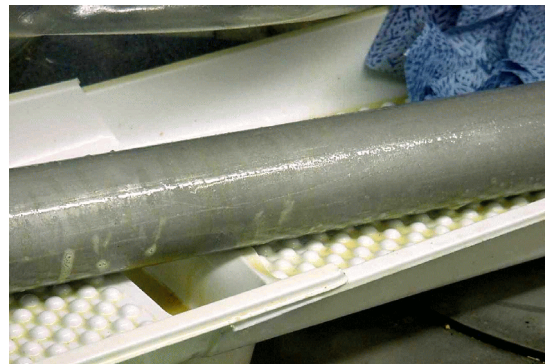
	cpm Beta 260 K	cpm Beta 270 K	cpm Beta 290 K	cpm Beta 280 K	cpm Beta 270 K						
	Drain line - source of gamma radiation underneath the stainless steel trench surface										
	cpm Alpha 21	cpm Alpha 11	cpm Alpha 15	cpm Alpha 20	cpm Alpha 18	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	
Smear dpm/100cm2-Alpha (* denotes less than)	20*	20*	20*	20*	20*	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	
Smear dpm/100cm2-Beta	200*	200*	200*	200*	1,312	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	EAI Decon Trial	

Table 3.3 - Results of the Decontamination of the FRS Fuel Rack Sections

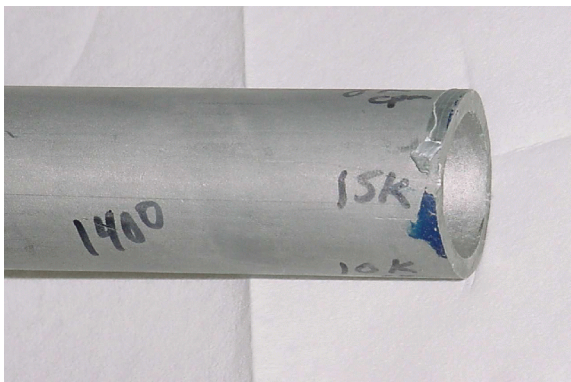
		Fuel Rack Section A EAI Decontamination			Fuel Rack Section B Contrad 70 Decontamination (Followed by single EAI Decontamination)			
		Initial	0200 /0300 Decon	0100 Decon	Initial	Contrad 70 Decon	Contrad 70 Decon	EAI Decon
Loose contamination dpm/100cm ² (outside fuel rack section)	α	<50	<50	<20	<50	<50	<20	<20
	α	<50	<50	<20	<50	<50	<20	<20
	βγ	625,000	7,500	<200	257,500	2,051	1,328	<200
	βγ	625,000	37,500	<200	375,000	4,132	1,413	<200
Loose contamination dpm/100cm ² (inside fuel rack section)	α	<50	<50	<20	<50	<20	<20	<20
	α	<50	<50	<20	<50	<20	<20	<20
	βγ	137,500	1,074	<200	7,500	<200	<200	<200
	βγ	37,500	2,159	<200	6,250	<200	<200	<200
Fixed Contamination mR/hr Contact	wo	30	1	1	18	10	10	0.2
	wc	1.5	0.5	0.5	0.7	0.5	0.5	0.1



(1) As Received



(2) EAI RADPRO Process



(3) Hot Spots Under TLC Coating



(4) Final

SECTION 4 TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

The competing technologies can be divided into two groupings; those which can be deployed in the same manner and within the same cost structure and those more complex decontamination processes which are costlier to deploy but achieve a similar high degree of decontamination efficiency.

For the purpose of the demonstration, competing technologies within the same cost and operability parameters were chosen. The results clearly show the EAI RADPRO® process to be considerably more effective. Therefore, for the purpose of judging the efficacy of the process against its performance competitors, the more effective decontaminations processes such as steam cleaning, scabbling and aggressive chemical processes were considered.

Steam cleaning, scabbling or chemical cleaning are methods that can be used to accomplish the removal of contamination from metal surfaces like as those found in hot cells (i.e., walls, ceilings and equipment surfaces). The summary presented in Table 4.1 shows how using other methods compare with using the EAI RADPRO® process.

Table 4.1 - Comparison with Alternative Technologies

Performance Factor	Baseline Technology Steam Vacuum Cleaning System	Alternative Technology En-vac Robotic Wall Scabblers	Chemical Cleaning	EAI RADPRO® Process
Personnel and Equipment	<ul style="list-style-type: none"> Personnel: <ul style="list-style-type: none"> 3 person crew Full time RCT Coverage Equipment: <ul style="list-style-type: none"> Robotic vacuum head for floor Steam wands for walls Various other equipment, control unit, water heater, vacuum with demister, cyclone, HEPA filter unit (each about 4' X 4') 	<ul style="list-style-type: none"> Personnel: <ul style="list-style-type: none"> 3 person crew Full time RCT Coverage Equipment: <ul style="list-style-type: none"> One Pentek Vac Pac Model 12A Rotopreen scabbling head 12A Needle Gun scabbling head 	<ul style="list-style-type: none"> Personnel: <ul style="list-style-type: none"> 2 person crew Intermittent RCT Coverage Equipment: <ul style="list-style-type: none"> Chemical tankage and spray equipment Chemical treatment equipment Waste grouting/ solidification equipment 	<ul style="list-style-type: none"> Personnel: <ul style="list-style-type: none"> 2 person crew Intermittent RCT Coverage Equipment: <ul style="list-style-type: none"> abrasive pads and cloths for swabbing Hand held spray bottles
System Cost	• \$194,000	• \$390,000	• Unknown	• \$100
Training Required	Radiation Worker (RADWORKER), Hazardous communications (HAZCOM) concerning equipment and hazards, Training typical of large equipment with high power requirements and very hot surfaces.	RADWORKER , HAZCOM, Training typical of large equipment with high power requirements and high pressures.	RADWORKER , HAZCOM, Training typical of hazardous (RCRA) chemicals and waste systems, training in waste treatment and packaging	RADWORKER , HAZCOM, Training typical of non-hazardous chemicals
Preparation Time	<ul style="list-style-type: none"> 24 hours to transport equipment to work site from on site storage 5 hours to setup equipment 	<ul style="list-style-type: none"> 24 hours to transport equipment to work site 3 hours to setup equipment 	<ul style="list-style-type: none"> Unknown, may require only a few hours. 4 hours to setup equipment 	<ul style="list-style-type: none"> ½ hour to transport equipment within work site, small portable equipment ½ hour to setup equipment
Production Rate	• 145.2 ft ² /hour	• 100 ft ² /hour	• 833 ft ² /hour	• 20 ft ² /hour (manual) 200 ft ² /hour (automated)
Typical Work Area Locations	• Very versatile, walls, floors, complex parts	• Large flat areas, walls, floors	• Very versatile, walls, floors, complex parts	• Flat surfaces, walls, floors, any surface where hand scrubbing (or remote analogue) is possible

Performance Factor	Baseline Technology Steam Vacuum Cleaning System	Alternative Technology En-vac Robotic Wall Scabbler	Chemical Cleaning	EAI RADPRO® Process
Access Required to Cell	<ul style="list-style-type: none"> Large open area and a hatch or doorway 	<ul style="list-style-type: none"> Large open area and a hatch or doorway 	<ul style="list-style-type: none"> Probably none, typical cell access is adequate 	<ul style="list-style-type: none"> Small cell penetration for swabs and pads.
Footprint of Equipment	<ul style="list-style-type: none"> Estimated 64 ft² 	<ul style="list-style-type: none"> Estimated 120 ft² 	<ul style="list-style-type: none"> Estimated 100 ft² for tanks and waste equipment 	<ul style="list-style-type: none"> N/A
Work Area Hazards	<ul style="list-style-type: none"> Heat, steam, high voltages 	<ul style="list-style-type: none"> High pressure water, high voltages 	<ul style="list-style-type: none"> Chemical hazards (corrosive, RCRA hazardous) 	<ul style="list-style-type: none"> Chemical hazards (irritant)
Waste Type and Volume	<ul style="list-style-type: none"> Water, 0.05 ft³/ ft² 	<ul style="list-style-type: none"> Solid abrasive grit, filters, 0.11 ft³/ft² 	<ul style="list-style-type: none"> Hazardous solution, 0.027 ft³/ ft² 	<ul style="list-style-type: none"> Non-Hazardous solid, 0.016 ft³/ft²
Portability	<ul style="list-style-type: none"> Fairly portable (small size units and not too heavy) 	<ul style="list-style-type: none"> Not very portable (Very heavy, large size, cell mounting anchors required for wall unit) 	<ul style="list-style-type: none"> Not very portable (additional tanks, pumps and equipment may be required) 	<ul style="list-style-type: none"> Very portable typical cell penetrations may be used for posting in chemicals and swabs
Utilities/Energy Requirements	<ul style="list-style-type: none"> 110V, 20A 480V, 100A, 3ph 	<ul style="list-style-type: none"> 440 V, 120kVa, 3ph 100 psi, 640 scfm compressed air 	<ul style="list-style-type: none"> Chemical handling equipment 	<ul style="list-style-type: none"> None

Technology Applicability

Major advantages associated with using the EAI RADPRO® process for the purpose of decontamination of hot cells to achieve dose reduction for manned access include no capital investment in new equipment, simple deployment using existing in-cell equipment, waste is compatible with existing disposal pathways, low rates of waste generation and ease of waste treatment and disposal. The technology is commercially available, with considerable performance data available from applications around the DOE complex, specifically Rocky Flats Environmental Technology Services and Los Alamos National Laboratories glove box decontaminations.

The technology is appropriate for consideration where substrates of moderate geometric complexity are radioactively contaminated to the degree where decontamination for dose reduction and/or re-categorization of the waste form is desired for reasons of ALARA and cost efficiency. The technology should receive strong consideration for the decontamination of steel-lined hot cells and in applications where a minimal volume of solid secondary waste is desired. Typically, the latter is associated with applications where an operational liquid radioactive treatment infrastructure is unavailable. The work performed under this LSDDP did not evaluate the ability of the EAI RADPRO® process to be deployed for decontamination of internal surfaces of radiologically contaminated process plant equipment by a process of recirculation through the plant or immersion of the components. Both of these applications are of potential value and therefore warrant consideration.

Patents /Commercialization/Sponsor

The EAI RADPRO® Process is available from:

EAI Inc.

640 Marlboro Street

Route 101

Keene, New Hampshire. 03431.

Contacts:

Randy Martin EAI Inc

(603) 352-3888

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SECTION 5

COST

Methodology

In order to compare the cost effectiveness of the EAI RADPRO® process, technologies of equal decontamination efficiency rather than equal cost structure were evaluated. The technologies for comparison are the Steam Vacuum Cleaning Technology, the En-vac Robotic Wall Scabbler, and a common chemical wall flushing method. The steam technology evaluation information is taken from the a DOE report where its performance is documented. This would be a comparable method to the EAI process because of its usefulness on a variety of surfaces, including stainless steel, and its ability to be directed remotely. All of the data applied in the comparison was generated by work performed by the Idaho National Engineering and Environmental Laboratory.

The En-vac system is truly a robotic unit, with operator controls well removed from the contaminated workpiece. The data for comparison was provided during an earlier evaluation test of the En-vac system by the Idaho National Engineering and Environmental Laboratory.

The closest method for comparison to the EAI RADPRO® process is chemical decontamination. Most hot cells were designed for chemical decontamination, so the systems for chemical application are readily available. One requirement for chemical decontamination is a chemical waste treatment system. For the WVDP, or many facilities undergoing D&D, this chemical waste treatment system is not available. This does not preclude the use of the chemical decontamination system, but does enforce certain additional costs for point of use waste treatment and disposal systems.

Cost Analysis

The operational costs to deploy the EAI process (without automation of application or removal) either by hand or using an in-cell manipulator, is dominated by labor cost. For this report a 10 X 10 foot cell, 20 feet high, was assumed, the total amount of area (walls and floor) to be cleaned being approximately 2000 ft². The time required to perform decontamination (application and removal) would be approximately 100 hours. Assuming a burdened labor rate of \$60/hour, for two workers yields \$12,000. The cost for EAI process chemicals, mobile lab and technician is approximately \$25,000 per 60-hour week. To clean 2000 ft² would require 100 hours at a cost of \$41,500 for EAI plus the \$12,000 for host site labor, totaling \$53,500. The waste would be about 10 ft³ based on the lightly compacted rate of 0.005 ft³/ft² at a cost of \$150/ft³, totaling \$1,500. This provides a total project cost of \$55,000 and yields a unit cost of \$27.50 ft².

It should be noted that automation of the application step through use of a rotary brush/pad and automation of removal by steam cleaning would reduce the cost by an order of magnitude because of the increase in productivity. It would however increase the complexity of remote in-cell operations and require some investment in equipment.

Comparison of these costs to some commonly available decontamination technologies is shown in Table 5.1.

Table 5.1 - Decontamination Method Cost Comparison					
Method	System	Material	Labor	Waste Disposal	Total
EAI RADPRO®	\$0	\$41,500 (EAI)	\$12,000	\$1500	\$55,000
Steam Vacuum	\$194,000	\$0*	\$3,303	\$15,000	\$212,300
En-vac Robotic Scabbler	\$390,000	\$0*	\$3,600	\$33,000	\$426,600
Chemical Decon	\$0* (Infrastructure in place)	\$0* (Chemicals typically on site)	\$288	\$16,200	\$16,488
* Essentially no significant costs in this area for these methods					

One definite advantage for application in hot cells such as the WVDP Head End Cells is the portability and mobility of the EAI RADPRO® process over the other alternatives. Mobilization of the EAI RADPRO® process is the simplest of any alternatives as the process requires only abrasive pads, cloths and small containers, such as 500 ml atomizer bottles, to deploy the process. The other systems have several components that are large and not easily transported by a person.

The En-vac system would require overhead anchors (which are not typically available and may require cell modification) during its use. Placement and retrieval of this tool would be difficult, as it appears to weigh several hundred pounds and is not man-portable, thus requiring a larger personnel dose to mobilize. A portion of the En-vac accessory equipment weighs over 3 tons, and requires 440V, 3 phase electrical support with a very large compressed air service. Mobilizing and maintaining this equipment requires a significant support crew. The control cables, tethers and vacuum hoses are also large enough to require maintaining an open cell entrance during use.

The steam cleaner likewise requires significant resources and cumbersome hoses. It has a trailer mounted vacuum system and steam generator that has electrical power requirements similar to the En-vac system as well as a 3 gal/minute water requirement. This water would require treatment in the WVDP (dry) cells. Finally, chemical cleaning, while the easiest to implement from a historical perspective, is very problematic when used in nuclear facilities. Again, suitable cell containment (secondary containment) may not be available and secondary waste treatment is required.

Cost Conclusions

The EAI RADPRO® process offers flexibility, in that it can be integrated with most baseline decontamination technologies such as wiping and steam cleaning at a cost of approximately \$15/ft², transforming these baseline technologies into technologies that have the capability to re-categorize waste streams. Therefore, the EAI RADPRO® process can be readily factored into D&D planning where it can be demonstrated to add value (i.e., projects where cost savings from re-categorization of waste or dose reduction to allow man access to D&D over robotic/remote means can be achieved). The robustness, simplicity of use, and predictable unit cost rates of the EAI RADPRO® process makes it advantageous to consider over other innovative technologies.

The EAI RADPRO® process was not evaluated for in-situ recirculation or ex-situ immersion decontamination application, which forms the bulk of large system decontamination requirements. Therefore, no comment can be offered with regard to said applications. The data in this document should not be considered transferrable for such use.

SECTION 6 OCCUPATIONAL SAFETY AND HEALTH

Required Safety and Health Measures

The EAI RADPRO® process, when used as directed, presents no specific health and safety issues that require mitigation, other than appropriate PPE for working with chemical irritants and any job specific radiological containment and protective equipment. The chemical formulations if used incorrectly, for example by mixing the 0100 with the 0300, are reactive and under certain conditions will generate noxious fumes (ammonia, ammonium fluoride) and potentially cause over pressurization of containers. This can be prevented by periodic venting. Self-venting containers for storage of chemicals is recommended. This not a process specific issue but more one of conventional chemical safety, which teaches the appropriate separation of strong bases and strong acids, more specifically nitric acid and organic compounds.

Conducting a thorough review of Material Safety Data Sheets (MSDS) for the chemical formulations 0100, 0200, and 0300 is recommended before process deployment begins. Material handling should be performed with latex gloves, safety glasses and other approved protective equipment assigned by an industrial hygienist to ensure against the potential for exposure to any irritating substance during use.

Safety and Health Lessons Learned from Demonstrations

Ensure adequate ventilation exists where the chemical formulations are prepared for application. In the event adequate ventilation may not be achieved using engineering controls, users should consider wearing chemical respirators.

Avoid contact with skin to prevent dermal effects. Users should wear chemical protective gloves and safety glasses to prevent absorption through the skin and eyes.

Implement a comprehensive training program including technology specific training, PPE training, Hazard Communication (HAZCOM) training, and Radiation Worker I & II training.

Comparison with Baseline and Alternative Technologies

The EAI RADPRO® process was deployed using standard operating procedures for manual decontamination work, with due consideration given to the potential chemical hazard and skin irritant issues.

The EAI RADPRO® process was deployed in the same manner as the baseline technology, with the only added complexity being the use of complex chemical formulations, which require an “expert user”. This has a minimal impact on health and safety and requires the addition of only minor modification to operating procedures to mitigate the slight increase in hazard above that experienced when using strippable coatings alone. The EAI RADPRO® process presents no increase in hazard over other acid or alkali based proprietary decontamination formulations/products.

SECTION 7 REGULATORY AND POLICY ISSUES

Regulatory Considerations

No technology specific regulatory permits are required for deployment of the EAI RADPRO® process. The process can be used under the requirements of 10 CFR Parts 20 and 835 for protection of workers and the environment from radiological contamination and 29 CFR, OSHA worker requirements.

Risks, Benefits, Environmental and Community Issues

Risks associated with the EAI RADPRO® process are those typical of the standard risks of use of chemicals in industrial settings. These risks to worker safety are mitigated by following the vendor (EAI) supplied expertise and data, and guidance provided in the MSDS sheets.

The benefits of the process are the ability to employ standard decontamination practices used for simple “wiping down” of loose contamination and expand their decontamination effectiveness to include the ability to solubilize and remove from the substrate surface chemically bonded radionuclide contamination and the metallic substrate oxide films associated with them.

There are no community impacts that arise from use of the EAI RADPRO® process.

SECTION 8

LESSONS LEARNED

Implementation Considerations

The EAI RADPRO® decontamination process is a complex blend of inorganic acids, organic acids, complexing agents, surfactants and other proprietary formulations. As such it should be considered a process that requires an “expert user” for the initial development of a deployment scenario. The formulation is non-hazardous and is classed as non-corrosive for the purpose of DOT regulations. It is simple to apply and needs only precautions for personnel handling chemical irritants. The complex formulation of inorganic acids, organic acids and organic compounds can, if inappropriately used, give rise to noxious fumes and cause over-pressurization of containers containing mixtures of the formulations. For these reasons, the technical direction supplied by the vendor, EAI, and the guidance supplied in the MSDS sheets must be rigorously followed.

For operators trained in routine decontamination operations, the process can be readily utilized with little additional training. The simple hands on (or remote) application achieves high decontamination factors and produces a solid secondary waste stream that is compatible with existing waste disposal pathways and disposal site WAC's.

The technology should be considered for the re-categorization of waste streams from CH-TRU and RH-TRU waste to SCO/LLW waste, and alternatively Class B and Class C waste to Class A LLW. The technology has exhibited the desired capabilities for the declassification of LLW to unrestricted release, though the current regulatory and economic drivers cast doubt on the public acceptability and cost efficiency of that objective.

APPENDIX A
REFERENCES

1. EAI RADPRO® Technology - EAI Inc, Randy Martin, EAI. October 2002.
2. EAI Memo dated December 10, 2002 - Certification of Chemical Formulations and TCLP data.
3. Remote Demonstration of the ElectroDecon System, R. Dremmer, R. Lane, INEEL. BWXT Idaho January, 2003

APPENDIX B
ACRONYMS AND ABBREVIATIONS

A&PC	Analytical and Process Chemistry
ALARA	As Low As Reasonably Achievable
CFR	Code of the Federal Regulations
D&D	Decontamination and Decommissioning
DOE	U. S. Department of Energy
DOT	Department of Transportation
EAI	Environmental Alternatives Inc.
FRS	Fuel Receiving and Storage
LSDDP	Large-Scale Demonstration and Deployment Project
MSDS	Material Safety Data Sheet
MSM	Master-Slave Manipulator
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
RCRA	Resource Conservation Recovery Act
WAC	Waste Acceptance Criteria
WVDP	West Valley Demonstration Project